Total Maximum Daily Load for Dissolved Oxygen & Nutrients for the Ocklawaha River Marion County, Florida

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1.0 Introduction

1.1 Purpose of Report

This report presents a Total Maximum Daily Load (TMDL) for dissolved oxygen (DO) and nutrients for three different segments of the Ocklawaha River. Using the methodology to identify and verify water quality impairments described in Chapter 62-303 (Identification of Impaired Surface Waters, which is commonly referred to as the Impaired Waters Rule, or IWR), Florida Administrative Code, these segments were verified as impaired for DO and nutrients, and these waters were included on the verified list of impaired waters for the Ocklawaha Basin that was adopted by Secretarial Order on August 26, 2002. The TMDL process quantifies the amount of a pollutant that can be assimilated in a waterbody, identifies the sources of the pollutant, and recommends regulatory or other actions to be taken to achieve compliance with applicable water quality standards based on the relationship between pollution sources and in-stream water quality conditions

1.2 Identification of Waterbody

The Ocklawaha River basin covers 2,769 square miles within Marion County, FL in north central Florida's peninsula (Figure 1). The river is approximately 96 miles in length with headwaters located at Lake Griffin's outfall. The river flows generally north and then bends sharply eastward emptying into the St. John's River. The Ocklawaha River is considered a Class III water (recreation, propagation and maintenance of a healthy, well-balanced population of fish and wildlife) and is included in Hydrologic Unit Code (HUC) 03080102.

Two diverse hydrological regions constitute the Ocklawaha basin. The first, comprising the northern and eastern half of the basin, includes a pattern of lakes, tributaries, and wetlands. The second part lies generally west of Interstate 75 and is also known as the Florida ridge. This area is largely drained internally with a defined sub-surface flow system.

The Upper Ocklawaha River Basin (UORB) lends the majority of its flow to the upper Ocklawaha chain of lakes (i.e Lakes Griffin, Eustis, Dora, Harris, and Apopka) as well as other small tributaries. Moving downstream some 20.5 miles from the source, Silver River empties into the Ocklawaha contributing an average of 685 cfs of water (USGS gauging station 2239500).

For assessment purposes, the watersheds within the Ocklawaha River Basin have been broken out into smaller watersheds, with a unique waterbody identification (WBID) number for each watershed. The Department has divided the Ocklawaha River into five sub-areas. The list below moves upstream from the confluence of the Ocklawaha River with the St. John's River:

- 2740A - between Kirkpatrick Dam and the Ocklawaha/St. John's River confluence
- 2740B - between Eureka and Kirkpatrick Dam (including Rodman Reservoir)
- 2740C - between Silver River confluence and Eureka Dam
- 2740D - between Moss Bluff Lock and Dam and Silver River confluence
- 2740F - between the source of the Ocklawaha River and Moss Bluff Lock & Dam

The three WBIDs addressed by this TMDL are 2740C, D, & F and were included on the 1998 303(d) list of impaired waters for dissolved oxygen, nutrients, and total coliforms (Figure 2). Dissolved oxygen and nutrients were verified impaired under the IWR for these three WBIDs and are the focus of this TMDL.

2.0 Statement of Problem

The UORB is located primarily in a large lowland area between the Mount Dora Ridge to the east and the Ocala Uplift District to the west. In many areas, the valley floor intersects the potentiometric surface resulting in numerous springs and spring-fed lakes. Karst terrains are present throughout the area due to the soluble carbonate rock and the nutrient rich soils have combined to produce naturally productive hardwater lakes.

During the 1800s resources were developed for tourism, agricultural, and commercial industry. According to the SWIM Plan (Fulton, 1995), impacts of urban development within the basin were first documented in the late 1940s. Eutrophication of surface waters was accelerated by the direct discharge of domestic, industrial, and agricultural wastes. In addition, construction of control structures and channelization of the system along with destruction of aquatic habits contributed to declines in water quality.

In 1987, the Florida Legislature adopted the Surface Water Improvement and Management (SWIM) Act, which directed Water Management Districts to adopt methodologies to identify waters in need of restoration and/or preservation. In 1989, the SJRWMD adopted a SWIM plan for the restoration of the UORB. The UORB encompasses 638 square miles, extending from the Apopka-Beauclair water control structure north of Lake Apopka to State Road 40 near Ocala. Segments 2740F and 2740D are included within the northern region of the UORB SWIM boundary.

In 1995, the SJRWMD developed an interim Pollutant Load Reduction Goal (PLRG) for phosphorus (Fulton, 1995) in the UORB lakes based upon trophic state modeling. PLRGs represent estimated reductions in pollutant loadings from stormwater needed to preserve or restore beneficial uses of receiving waters.

Key water quality parameters for the three WBIDs are presented in Figures 3(a,b,c,d)-5(a,b,c,d). Table 1 summarizes DO and annual Chlorophyll a averages that were used to assess these segments under the IWR. Statistical summaries of key water quality parameters are presented for the three WBIDs in Table 2.

3.0 Description of the Applicable Water Quality Standards and Numeric Water Quality Target

The Ocklawaha River is a Class III waterbody with designated uses of recreation, propagation and maintenance of a healthy, well balanced population of fish and wildlife. Class III water quality criteria applicable to the observed impairment include the minimum DO of 5.0 mg/l and the narrative nutrient criterion (nutrient concentrations of a body of water shall not be altered so as to cause an imbalance in natural populations of aquatic flora or fauna). Because the nutrient criterion is narrative only, a nutrient related target was needed to represent levels at which imbalance in flora or fauna are expected to occur.

Specific to nutrients (Chlorophyll a) in streams, the IWR has established thresholds to evaluate impairment. These thresholds indicate impairment when annual mean concentrations of Chlorophyll a are "greater than 20 ug/l or if data indicate annual mean Chlorophyll a values have increased by more than 50% over historical values for at least two consecutive years

Using a binomial distribution, it was determined that there were greater than 10% exceedances of the State criteria for DO with a 90% confidence level. Annual Chlorophyll a concentrations were also verified as impaired based upon the thresholds in the IWR.

4.0 Assessment of Sources

4.1 Types of Sources

An important part of the TMDL analysis is the identification of source categories, source subcategories, or individual sources of phosphorus in the watershed and the amount of pollutant loading contributed by each of these sources. Sources are broadly classified as either "point sources" or "nonpoint sources." Historically, the term point sources has meant discharges to surface waters that typically have a continuous flow via a discernable, confined, and discrete conveyance, such as a pipe. Domestic and industrial wastewater treatment facilities (WWTFs) are examples of traditional point sources. In contrast, the term "nonpoint sources" was used to describe intermittent, rainfall driven, diffuse sources of pollution associated with everyday human activities, including runoff from urban land uses, runoff from agriculture, runoff from silviculture, runoff from mining, discharges from failing septic systems, and atmospheric deposition.

However, the 1987 amendments to the Clean Water Act redefined certain nonpoint sources of pollution as point sources subject to regulation under EPA's National Pollutant Discharge Elimination Program (NPDES). These nonpoint sources included certain urban stormwater discharges, including those from local government master drainage systems, construction sites over five acres, and from a wide variety of industries (see Appendix A for background information about the State and Federal Stormwater Programs).

To be consistent with Clean Water Act definitions, the term "point source" will be used to describe traditional point sources (such as domestic and industrial wastewater discharges) AND stormwater systems requiring an NPDES stormwater permit when allocating pollutant load reductions required by a TMDL (see Section 7). However, the methodologies used to estimate nonpoint source loads do not distinguish between NPDES stormwater discharges and non-NPDES stormwater discharges, and as such, this source assessment section does not make any distinction between the two types of stormwater.

4.2 Source Loads

There are no permitted facilities with direct point source discharges to the Ocklawaha River. Therefore, to link water quality to probable sources, surrounding land use patterns and water quality data from Lake Griffin and Silver River must be considered. In-stream or ambient biochemical reactions between oxygen demanding substances and dissolved oxygen should also be considered. The report thus turns its attention to Lake Griffin as the primary determinant of the Ocklawaha's water quality for WBIDs 2740F, C & D.

The direct discharge of water from Lake Griffin serves as the source or headwaters for the Ocklawaha River. Thus, the lake acts as a loading source that determines nearly all water quality attributes (neglecting direct run-off into the river) downstream.

The second major loading source to the Ocklawaha River is Silver River. This confluence is located at the 2740C/D WBID boundary (Figure 2) and has been shown (Magley 1998, 2000) to be a significant contributing factor to the Ocklawaha's flow from the confluence on downstream. Silver River is not believed to be a direct loading source causing the observed impairments based largely on its low Chlorophyll a concentrations and its at or above State compliance for dissolved oxygen concentrations. The Silver River may indirectly contribute to nutrient impairments in WBID 2740C or further downstream due to nitrate levels of nearly 1 mg/l.

Land use for WBID's 2740C, D, & F are given graphically and in tabular form in Figure 6 and Table 3, respectively. Wetlands comprise the largest land use of the Ocklawaha basin at 47.3%. Urban areas, water, and upland forests each comprise nearly 10% of the basin while barren land occupies the smallest area at only 0.14%.

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TABLE 3: INDIVIDUAL LEVEL 1 LAND USE PERCENT CONTRIBUTIONS TO IMPAIRED WBIDs 2740 C, D, & F ALONG THE OCKLAWAHA RIVER

Land Use	Percent Contribution
Urban & Built Up	10.7
Agriculture	9.4
Rangeland	8.1
Upland Forests	10.9
Water	10.6
Wetlands	47.3
Barren Land	0.14
Transportation, Communication, & Utilities	2.8

A variety of soils are within the basin with the dominant types being chobee, wauchula, okeelanta, paola, samsula, placid, and adamsville. Chobee, wauchula, and okeelanta soils are commonly deep and very poorly drained and for the area of interest are found primarily in the downstream portions of the river. The implication here is that these three soils show a high degree of run-off, thus not allowing for sufficient percolation of water into the surficial aquifer. The paola series is also deep, but excessively drained and is found primarily in and around the river's headwaters. Excessively drained soils like paola allow for very low run-off and appreciable percolation of water into the surficial aquifer. Also found in and around the source region of the Ocklawaha River are the soil types of samsula, placid, and adamsville. These three types, like chobee, wauchula, and okeelanta are poorly drained with high run-off and allow little percolation of water into the surficial aquifer.

According to the U.S. Census Bureau for 2000, the population density in Marion County varied quite dramatically from east to west (Figure 7). The entire county east of the river has a population density of 38 people per square mile while areas west of the river show densities ranging from 88-555 people per square mile.

5.0 Loading Capacity – Linking Water Quality and Pollutant Sources

Lake Griffin represents the headwaters for the Ocklawaha River has been verified impaired for nutrients and un-ionized ammonia due to increased nutrient loading from agriculture and development in the basin. Maximum Chlorophyll a concentrations typically occur in Lake Griffin during the spring and summer period as a result of increased light levels, daylength, and water temperatures. Algal populations can increase rapidly and the production of oxygen as a result of photosynthesis during daylight hours and respiration or consumption of water from the water column at night can result in large diurnal fluctuations of DO in the water column. These fluctuations in water quality are quite evident in segments 2740F and 2740D of the Ocklawaha River. A fraction of the increased biomass produced in Lake Griffin also becomes part of the organic material that is transported down the Ocklawaha River and broken down by microbes or settles to the bottom. Both microbial breakdown of this material in the water column or in the bottom sediments of the river exert a biochemical oxygen demand that reduces oxygen levels in the water column.

Water levels in Lake Griffin are also regulated by the Moss Bluff Lock and Dam (located on border of WBIDs 2740D and 2740F). The regulation schedule maintains an elevation range of 58 to 59.5 feet National Geodetic Vertical Datum (NGVD) in Lake Griffin. Based upon daily flow records at Moss Bluff over the 1995 – 2002 period, flows varied from 10 cfs (0.3 m^3/s) to 1,970 cfs (55.8 m^3/s) with mean and median values of 177 cfs (5.0 m^3/s) and 43 cfs (1.2 m^3/s), respectively. Historically (1943 – 2001), Lake Griffin contributes, on average, nearly 248 cfs to the upper Ocklawaha River (USGS gauge 02238500 at Moss Bluff). The combination of seasonal fluctuations in algal production and the discharge schedule have a significant impact on both flow and water quality characteristics of the Ocklawaha River.

Lake Griffin (WBID 2814A) was verified impaired for un-ionized ammonia and nutrients in Florida's 2002 303(d) list of impaired waters. According to data from Lake Griffin over the 1989-2002 period, the average Chlorophyll a concentration of the lake was nearly 137 ug/l. The average dissolved oxygen for Lake Griffin over the same period was 8.6 mg/l, 5mg/l or less is considered impaired for Class III freshwater streams (Chapter 62-302, F.A.C.). Not of coincidence, three downstream WBIDs (2740C, D, & F) (Figure 2) of the Ocklawaha River were listed impaired for nutrients and dissolved oxygen. It thus becomes necessary to statistically investigate Lake Griffin's dissolved oxygen and nutrient data.

The other significant loading source to the Ocklawaha River is Silver River. The Silver/Ocklawaha River confluence is located on WBIDs 2740C/D's border some 20.5 miles from the Ocklawaha's headwaters.

The immediate downstream waters from the confluence of the Silver and Ocklawaha Rivers constitutes WBID 2740C, which is impaired for dissolved oxygen and nutrients. Silver River introduces an average dissolved oxygen value to the Ocklawaha of 5.48 mg/l—a value that meets State criteria. Silver River's Chlorophyll a is well below the IWR stream threshold of 20 ug/l, reporting an average load of only 1.36 ug/l. Though Silver River is responsible for nearly 80% (next paragraph) of the Ocklawaha's flow downstream of the confluence, it is still believed that Lake Griffin is primarily responsible for the nutrient and dissolved oxygen impairment. This presumption is based on Lake Griffin's large Chlorophyll a values (Table 2) as well as Silver

River's low concentrations (Table 2). Silver River may have some influence on phytoplankton growth and sustainment, however, with an average nitrate-nitrite value of 0.93 mg/l and dilution effect on color in the river.

Magley (1998, 2000) completed work that compared the Silver River flow contribution to the Ocklawaha River at Connor and Eureka, FL and found that Silver River averaged 80% of the total flow to the Ocklawaha River (downstream of the confluence). The average of daily flows from 1932-2001 for USGS gauging station 02239500, located on Silver River, yielded an approximate value of 785 cfs (http://waterdata.usgs.gov/fl/nwis/sw). The respective maximum and minimum observed flows for the same period of record were 1,290 cfs and 350 cfs.

5.1 Model Selection and Application

5.1.1 DYNHYD5 Model Background, Methodology, and Assumptions Used for Simulations

DYNHYD5 is an enhancement of the Potomac Estuary hydrodynamic model DYNHYD2 (Roesch et al., 1979) derived from the original Dynamic Estuary Model (Feigner and Harris, 1970). DYNHYD5 solves the one-dimensional equations of continuity and momentum for a branching or channel-junction (link-node) network.

The model simulations encompassed a period of record between 01/01/1995 through 09/30/2001 and covered some 46 miles of the Ocklawaha River. This included all affected WBIDs (2740F, D & C) and stretched from the headwaters of Lake Griffin and ended just north of Eureka Dam in WBID 2740B (Figure 8).

This particular simulation involved taking daily variable flow data (upstream boundary flow and Silver River flow) over the period of simulation. The daily variable flow for the upstream boundary flow data came from USGS flow records (http://waterdata.usgs.gov/fl/nwis/sw) for the Moss Bluff site (USGS gauge 02238500).

The same method was used for Silver River's daily variable inflow using daily continuous flow data from USGS gauge 02239500 whereby. The river channel widths and lengths used in DYNHYD5 were determined using the measuring tool and aerial photography in Arc View 3.2a. Couple this input with observed total depth data, DYNHYD5 generated variable river channel volumes that were then linked to WASP. WASP also allows for the input of daily variable flow data and flow records from the previously mentioned USGS flow gauges were input directly into its interface. This could only be accomplished (noting that WASP is *not* a hydrodynamic model) because the slope of the Ocklawaha system from Lake Griffin downstream to Eureka Dam is very small (much less than 1 degree).

5.1.2 WASP 6.3 Model Background, Methodology, and Assumptions Used for Simulations

The Water Quality Analysis Simulation Program (WASP) version 6.3 is a modification of the original WASP model (Di Toro et al., 1983; Connolly and Winfield, 1984; Ambrose, R.B. et al., 1988). Time variable processes such as advection, dispersion, diffuse mass loading, and boundary exchanges constitute the basic program—all of which utilize the conservation of mass in space and time.

Water quality processes are simulated in internal subroutines and include the one used here for simple eutrophication kinetics (EUTRO). EUTRO simulates the transport and transformation reactions of eight state variables, interacting with one another through four basic systems: phytoplankton kinetics, the phosphorus cycle, the nitrogen cycle, and the dissolved oxygen balance. WASP solves the basic mass balance equation for each state variable.

Water quality data availability along the Ocklawaha River as well as those data available for Lake Griffin and Silver River often contained both spatial and temporal gaps. To account for these data voids, WASP employs a simple linear interpolation technique to help fill these gaps. Such interpolation schemes in themselves are considered assumptive.

Other assumptions evolved from the calibration process. Calibrating WASP (like any model) involved trying to match model predictions to observed data. To achieve this, certain constants and kinetic parameters are changed to help produce differing model simulations. This process of sensitivity analysis is often time consuming, but is all together necessary to calibrate a model.

A variety of methods can be used to test and see if a model is calibrated. These range from complicated statistical error methods to less-involved methods of graphical visual inspection.

Visual inspection was used here and involved trying to closely match both predicted and observed spatial patterns and the magnitudes of maximum and minimum values. Four evenly distributed points along the river that contained relative abundant observed water quality data were chosen to calibrate the model. Figure 8 shows where these points can be found as well as other details of the model's spatial domain.

5.2 TMDL Model Simulation

It is strongly believed that loading from Lake Griffin is the primary source for both nutrient and dissolved oxygen impairment for all three WBIDs of concern here—primarily due its own water quality and its serving as the Ocklawaha's headwaters. Lake Griffin is highly eutrophic with high algal biomass (see Table 2, Chlorophyll a concentrations), including nuisance blue-green algal (cyanobacteria) blooms and supersaturated dissolved oxygen levels (Table 2). Such conditions are present due to high nutrient loading in run-off from surrounding agriculture and urban land areas. Phosphorus, the primary parameter of concern in Lake Griffin, has three main sources that include muck farms, the Emeralda Marsh Conservation Area, and Haines Creek.

Since Lake Griffin is believed to be the primary source for dissolved oxygen and nutrient impairment here, reducing certain biological parameters into the lake are of utmost importance. As part of the evolving SWIM Program evaluations of the lake, the SJRWMD developed a new interim PLRG (Fulton et al. (2003)) for phosphorus in Lake Griffin. This PLRG became the basis for a phosphorus TMDL for Lake Griffin that requires a 66 percent reduction in the annual phosphorus load to the lake.

Reducing levels of TP in Lake Griffin would likely have a positive impact on the downstream waters of the Ocklawaha. First and foremost, reducing phosphorus to attain target concentrations like those proposed by SJRWMD would almost certainly decrease algal biomass production, subsequently transferring these results downstream into the Ocklawaha. Furthermore, dissolved oxygen concentrations downstream of Lake Griffin's headwaters would also be expected to improve.

Recently, a TMDL was completed by the Department for Lake Griffin involving phosphorous. The TMDL for Lake Griffin is expressed in terms of pounds per year, and represents the maximum annual load the lake can assimilate and maintain the narrative nutrient criterion. This TMDL was developed in conjunction with the existing PLRG from SJRWMD. The results of this work can be found in Table 4.

TABLE 4: TMDL COMPONENTS FOR LAKE GRIFFIN

WBID	Parameter	WLA		LA (lbs/year)	MOS	TMDL (lbs/year)	Percent Reduction
		Wastewater (lbs/year)	NPDES Stormwater (% Reduction)				
2814A	TP	N/A	66	26,902	Implicit	26.902	66[1]

[1] Note that this percent reduction was based upon the total annual average load which included atmospheric contributions

Since the Department believes strongly that Lake Griffin is the direct cause of the Ocklawaha River's impairment, the reduction of phosphorus proposed in table 4 will also be applied for this TMDL to bring the river under State compliance for water quality. To verify that this is indeed the case, the use of WASP, the water quality model described above, was employed.

WASP allows input of a variety of parameters, kinetics, and constants. Furthermore, the model allows the user to input a time series of water quality loads that help drive the boundary conditions. Lake Griffin served as the model's upstream boundary thereby forcing the model with the needed water quality loads. To accomplish this, seven years of Lake Griffin water quality data were assimilated and quality checked. These data included governing parameters such as total phosphorus, Chlorophyll a, dissolved oxygen, biochemical oxygen demand (BOD), ammonia, nitrate, and organic forms of nitrogen and phosphorus.

Nutrients (Chlorophyll a) and organic phosphorus (WASP does not allow for total phosphorus input) were chosen as the loading parameters in the model to scale back. These load reductions were checked for their influence to downstream water quality of Chlorophyll a, DO, BOD, and total phosphorus. The scaling factor used was that employed by the St. John's Water Management District's PLRG, whereby a 66% reduction in phosphorus was proposed for Lake Griffin to help meet State water quality standards (Table 4). This methodology is driven on the basis that load reductions in Lake Griffin would in turn help the downstream waters of the Ocklawaha River achieve applicable water quality criteria.

The results of the modeling effort are presented for each of the calibration segments (see Figure 8 for location of these segments) in table 5 (upstream segments) and table 6 (downstream segments) attached at the end of this document.

The maximum, minimum, median, mean, and standard deviation for Chlorophyll a, DO, BOD, and TP are given for four calibration points. These results are for the observed data, the model results without reducing Chlorophyll a and total phosphorus from Lake Griffin, and the model results with the load reductions from Lake Griffin.

As for nutrients, the model indicates that load reductions of total phosphorus and Chlorophyll a from Lake Griffin would alleviate the nutrient impairment as seen in elevated Chlorophyll a levels. This is true for all four segments and is represented both in mean and median values for Chlorophyll a. The model further indicates that total phosphorus values with these load reductions remain very low, reassuring because of its contribution to algal biomass production.

Mean values of dissolved oxygen present a slightly different story. The two upstream segments 8 and 20 (Figure 8, Table 5) show mean values that do not meet the State criteria of 5mg/L whereas the two downstream segments of 29 and 69 do (Figure 8, Table 6). This can be explained during the calibration process. During this time, the model (WASP) was predicting dissolved oxygen concentrations that were too high when compared to the observations. To compensate for this, sediment oxygen demand (SOD) rates were raised to help drive the DO down. This helped to better calibrate the model, but left SOD rates that were higher than what is typically observed. The results were dissolved oxygen predictions that were too low. These SOD rates cannot be changed at this time, however, because a calibrated model is necessary to make viable predictions.

6.0 Critical Conditions

The TMDL was based on long-term average conditions rather than critical/seasonal conditions because a) the methodology used to determine the assimilative capacity does not lend itself very well to short-term assessments, b) we are generally more concerned with the net change in overall primary productivity, which is better addressed on an annual basis, and c) the methodology used to determine impairment is based upon an annual average and requires data from all four quarters of a calendar year.

7.0 Determination of TMDL

The objective of a TMDL is to provide a basis for allocating acceptable loads among all of the known pollutant sources in a watershed so that appropriate control measures can be implemented and water quality standards achieved. A TMDL is expressed as the sum of all point source loads (Waste Load Allocations), nonpoint source loads (Load Allocations), and an appropriate margin of safety (MOS), which takes into account any uncertainty concerning the relationship between effluent limitations and water quality:

$$\mathbf{TMDL} = \sum \mathbf{WLAs} + \sum \mathbf{LAs} + \mathbf{MOS}$$

As mentioned in Section 4.1, the WLA is broken out into separate subcategories for wastewater discharges and stormwater discharges regulated under the NPDES Program:

$$\mathbf{TMDL} \cong \sum \mathbf{WLAs}_{\mathbf{wastewater}} + \sum \mathbf{WLAs}_{\mathbf{NPDES\ Stormwater}} + \sum \mathbf{LAs} + \mathbf{MOS}$$

It should be noted that the various components of the TMDL equation may not sum up to the value of the TMDL because a) the WLA for NPDES stormwater is typically based on the percent reduction needed for nonpoint sources and is accounted for within the LA, and b) TMDL components can be expressed in different terms [for example, the WLA for stormwater is typically expressed as a percent reduction and the WLA for wastewater is typically expressed as a mass per day].

WLAs for stormwater discharges are typically expressed as “percent reduction” because it is very difficult to quantify the loads from MS4s (given the numerous discharge points) and to distinguish loads from MS4s from other nonpoint sources (given the nature of stormwater transport). The permitting of stormwater discharges is also different than the permitting of most wastewater point sources. Because stormwater discharges cannot be centrally collected, monitored and treated, they are not subject to the same types of effluent limitations as wastewater facilities, and instead are required to meet a performance standard of providing treatment to the “maximum extent practical” through the implementation of Best Management Practices.

This approach is consistent with federal regulations [40 CFR § 130.2(I)], which state that TMDLs can be expressed in terms of mass per time (e.g. pounds per day), toxicity, or **other appropriate measure**. Table 7 below is a list of the TMDL components for each affected WBID. Because dissolved oxygen is a response variable, it cannot be expressed either as a load allocation or percent reduction.

TABLE 7: TMDL COMPONENTS FOR THE OCKLAWAHA RIVER

WBID	WLA (lbs/day)	Parameter	LA (lbs/year)	MOS	TMDL (lbs/year)	Percent Reduction
2740 C	N/A[1]	Nutrients	N/A[1]	Implicit	N/A[1]	N/A[1]
2740 D	N/A[1]	Nutrients	N/A[1]	Implicit	N/A[1]	N/A[1]
2740 F	N/A[1]	Nutrients	N/A[1]	Implicit	N/A[1]	N/A[1]

1

The above findings indicate that the proposed phosphorus load reductions of 66% applied to the Lake Griffin TMDL and then directly applied to this TMDL through computer modeling for phosphorus and Chlorophyll a will indeed be sufficient to bring the Ocklawaha River into State compliance for nutrients and dissolved oxygen. It is speculated that overly high values of SOD used in the modeling effort drove the mean and median values of DO to violate State criteria. However, as was stated, this was necessary to calibrate the model. It is likely that the proposed load reductions from Lake Griffin will bring all portions of the river under State compliance for dissolved oxygen.

The proposed TMDL above for the Ocklawaha River will require future work. The proposed load reductions of phosphorus in Lake Griffin will first need application before downstream impacts to the Ocklawaha’s water quality can be assessed. Further calibration to WASP is necessary, but impacts of this work may be small due to commonly observed large data gaps the model must compensate for.

Other activities such as proposed and on-going restoration events will also, without doubt, have beneficial impacts to the river’s water quality. Again, however, the magnitude of change these activities will procure remains to be seen.

[1] Modeling effort indicates that proposed load reductions used in Lake Griffin TMDL are applicable here and will bring the affected WBIDs for nutrients and dissolved oxygen under State water quality compliance.

7.1 Load Allocations (LAs)

The allowable LA is 26,902 lbs/year for TP. This corresponds to reductions from the existing nonpoint source loadings to Lake Griffin of 66 percent for TP. It should be noted that the LA includes loading from stormwater discharges regulated by the Department and the Water Management Districts that are not part of the NPDES Stormwater Program (see Appendix A).

Section 6 presented the two primary loading waterbodies to the Ocklawaha River. It will be the intent of this section to show the water quality loading of the verified impaired parameters of these waterbodies into the river as well as their contributing average flows.

Information about the water quality of Lake Griffin and Silver River will help in determining the TMDL. To achieve the necessary load reductions to help bring the verified parameters of the Ocklawaha River into State compliance, water quality computer modeling was employed. Specific to this TMDL, the WASP hydrodynamics model DYNHYD5 was chosen to generate the necessary hydrodynamics and was then linked to the EPA's WASP6.3 (Water Quality Analysis Simulation Program) for the determination of water quality.

7.2 Wasteload Allocations (WLAs)

NPDES Stormwater Discharges

As noted in Sections 4 and 7.1, load from stormwater discharges permitted under the NPDES Stormwater Program are placed in the WLA, rather than the LA. This includes loads from municipal separate storm sewer systems (MS4). Based on the 2000 census, the Lake Griffin watershed includes areas that will be covered by the MS4 Program, and the WLA for stormwater discharges is 66 percent reduction of current loading from the MS4. It should be noted that any MS4 permittees will only be responsible for reducing the loads associated with stormwater outfalls for which it owns or otherwise has responsible control, and is not responsible for reducing other nonpoint source loads within its jurisdiction.

NPDES Wastewater Discharges

There are no wastewater facilities authorized to discharge wastewater to these segments of the Ocklawaha River.

7.3 Relationship between Lake Griffin and Ocklawaha River TMDLs

Since Lake Griffin represents the headwaters of the Ocklawaha River it has a tremendous impact on water quality conditions in the river. Modeling DO and Chlorophyll a changes in the Ocklawaha River based upon implementation of the proposed phosphorus TMDL for Lake Griffin indicated significant water quality improvements in the river segments.

7.4 Margin of Safety (MOS)

An implicit margin of safety is assumed based upon TMDL developed for Lake Griffin. In that TMDL, a long-term (10-year) annual load budget and long-term average nutrient concentrations were used to determine the necessary phosphorus load reduction. Calculations of storm water runoff also assumed that there was no storm water treatment for lands already developed in 1987, while lands developed after 1987 were assumed to provide storm water treatment at levels equal to the average of 13 studies in Florida. Finally, in the determination of the target phosphorus concentration, the SJRWMD used the 25th percentile value from each estimate, which is considered a conservative level.

8.0 Seasonal Variation

As discussed earlier, potential nutrient impairments in streams are based upon calculated annual Chlorophyll a values. The IWR requires that water quality data from all four quarters of the calendar year in order to calculate an annual Chlorophyll a average.

Since DO is a gas, its saturation level is a function of water temperature and salinity. Increased water temperatures and/or salinities reduce the amount of oxygen that can remain in solution. Salinity is not a factor in the Ocklawaha River. Consequently, summer and early fall would represent periods of highest water temperature where DO saturation and DO would be expected to be lower. Algal production during these periods can increase oxygen levels during the day, however, the increased respiration will result in lower levels at night and the possibility of large diurnal fluctuations. Reductions in the algal biomass will reduce these fluctuations.

9.0 Next Steps: Implementation Plan development and beyond

Following adoption of this TMDL by rule, the next step in the TMDL process is to develop an implementation plan for the TMDL, which will be a component of the Basin Management Action Plan for the Ocklawaha Basin. This document will be developed in cooperation with local stakeholders and will attempt to reach consensus on more detailed allocations and on how load reductions will be accomplished.

The Basin Management Action Plan (B-MAP) will include:

- Appropriate allocations among the affected parties.
- A description of the load reduction activities to be undertaken.
- Timetables for project implementation and completion.
- Funding mechanisms that may be utilized.
- Any applicable signed agreements.
- Local ordinances defining actions to be taken or prohibited.
- Local water quality standards, permits, or load limitation agreements.
- Monitoring and follow-up measures.

It should be noted that TMDL development and implementation is an iterative process, and this TMDL will be re-evaluated during the BMAP development process and subsequent Watershed Management cycles. The Department acknowledges the uncertainty associated with TMDL development and allocation, particularly in estimates of nonpoint source loads and allocations for NPDES stormwater discharges, and fully expects that it may be further refined or revised over time. If any changes in the estimate of the assimilative capacity AND/OR allocation between point and nonpoint sources are required, the rule adopting this TMDL will be revised, thereby providing a point of entry for interested parties.

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FIGURE 1: OCKLAWAHA RIVER AND DRAINAGE BASIN

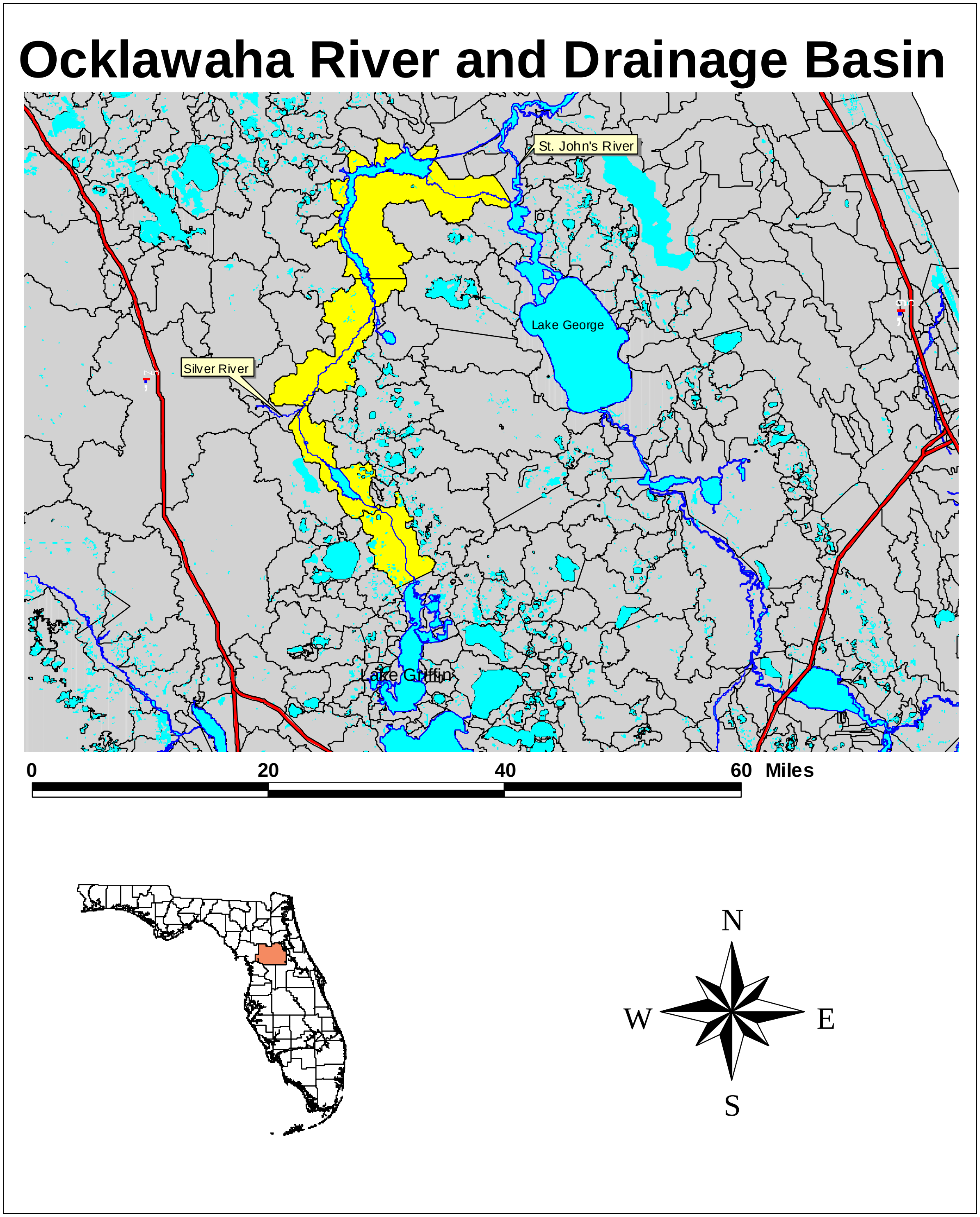


FIGURE 2: IMPAIRED WATERBODY IDENTIFICATION UNITS (WBIDs) FOR THE OCKLAWAHA RIVER

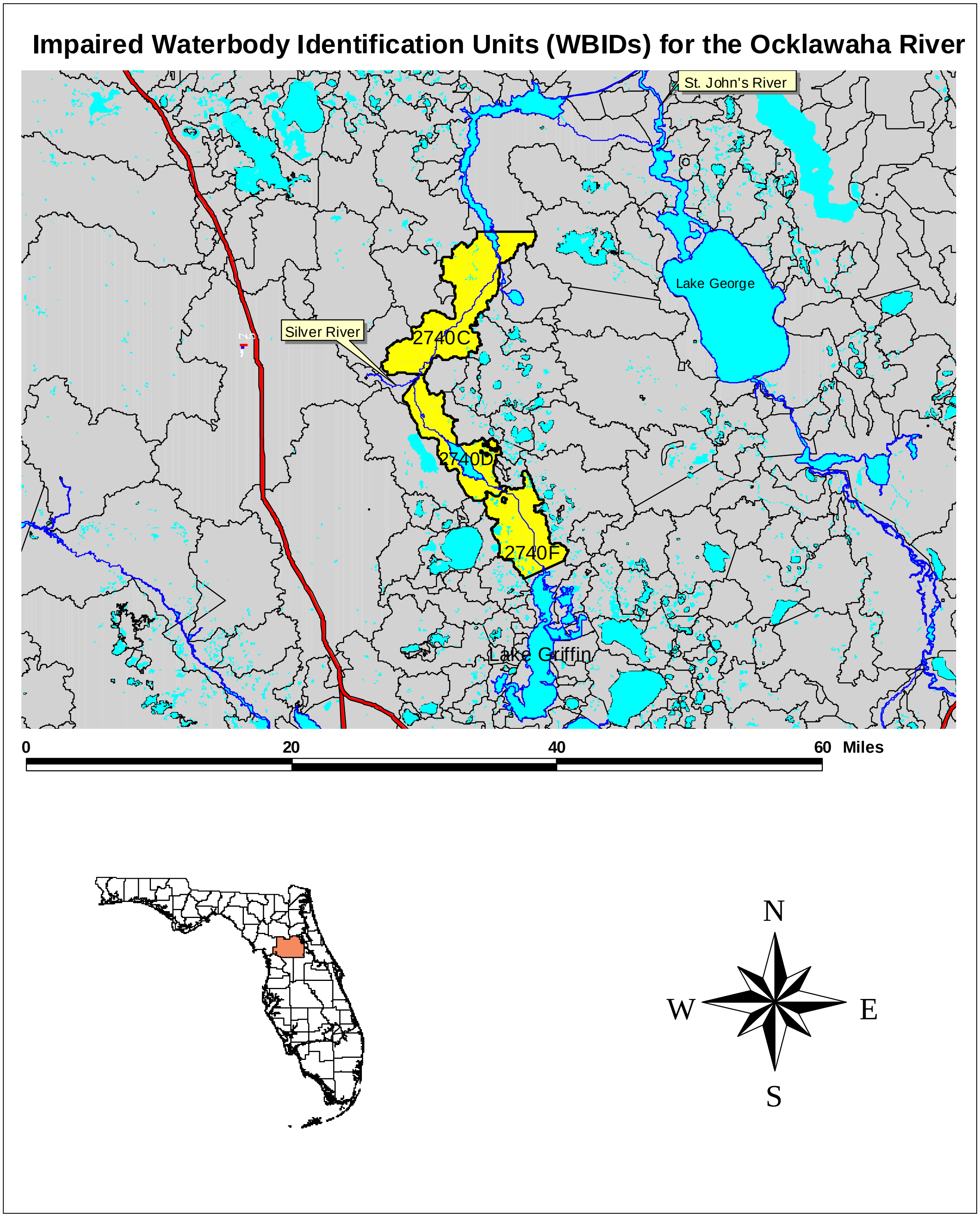
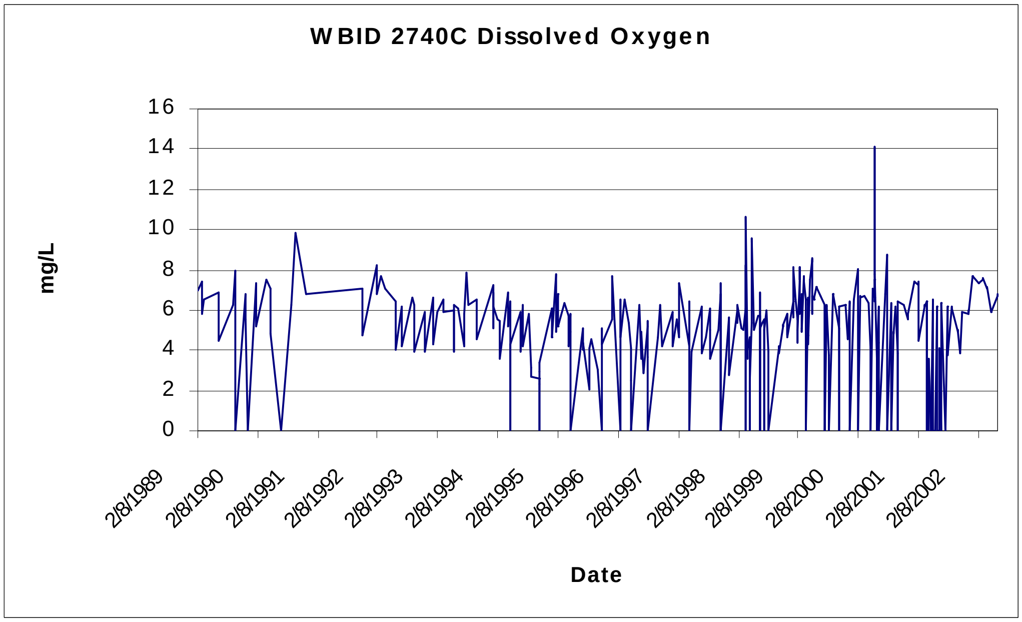


FIGURE 3A: WATER QUALITY TIME SERIES FOR DISSOLVED OXYGEN & BIOCHEMICAL OXYGEN DEMAND VALID FOR WBID 2740C



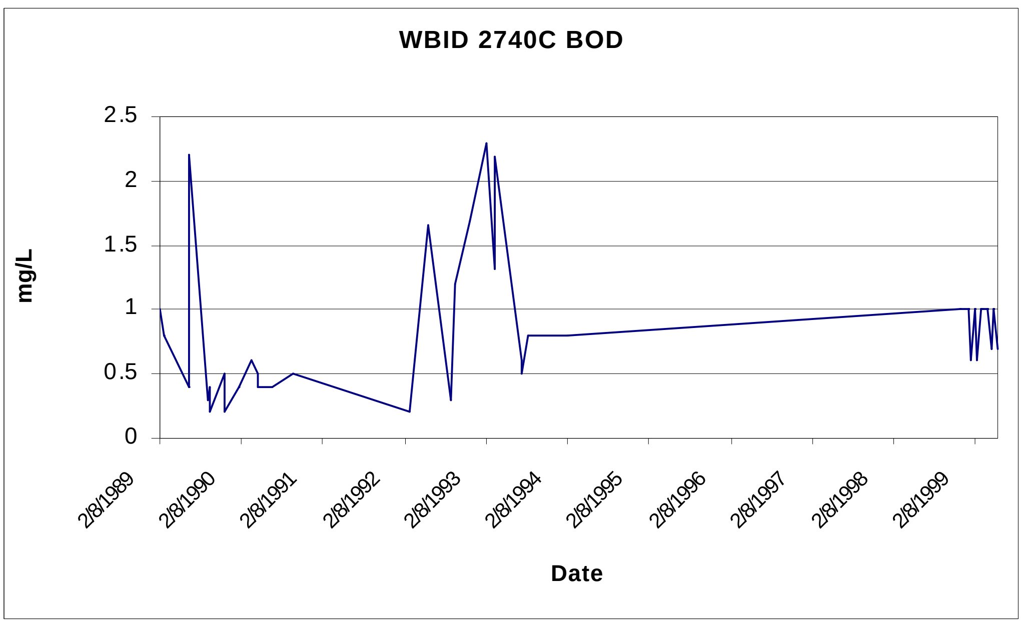
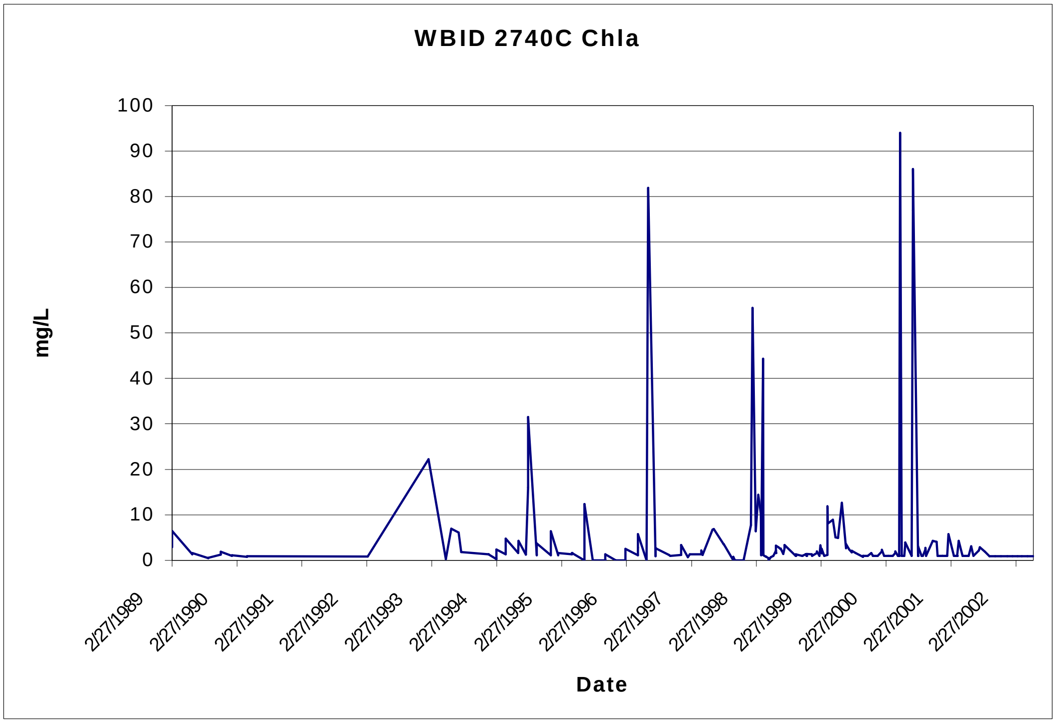


FIGURE 3B: WATER QUALITY TIME SERIES FOR CHLOROPHYLL a & TOTAL PHOSPHORUS VALID FOR WBID 2740C



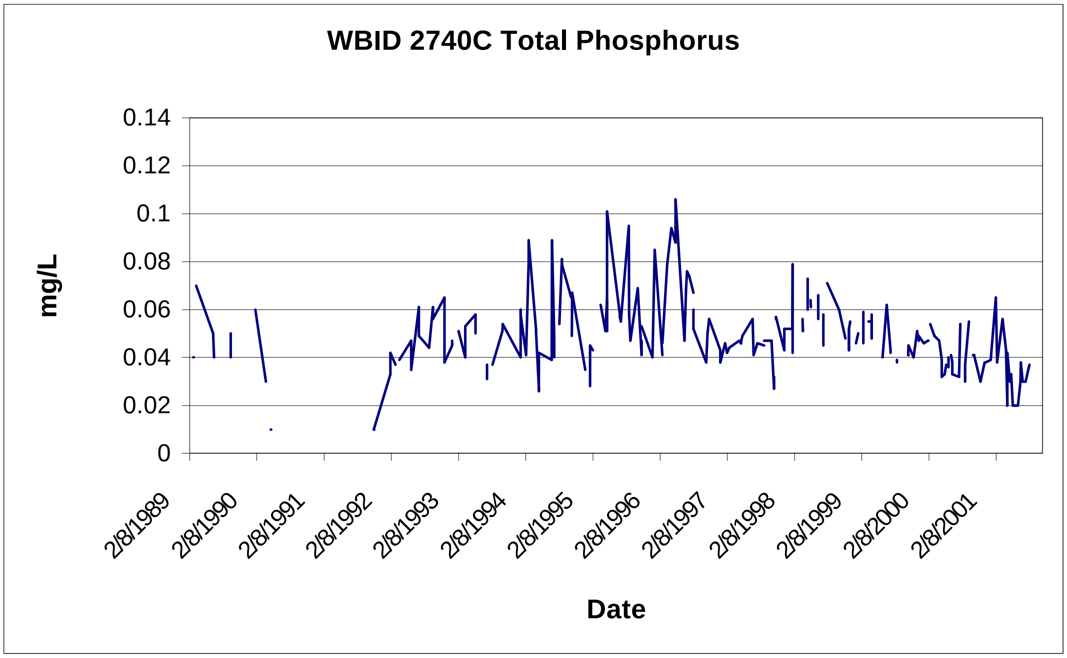
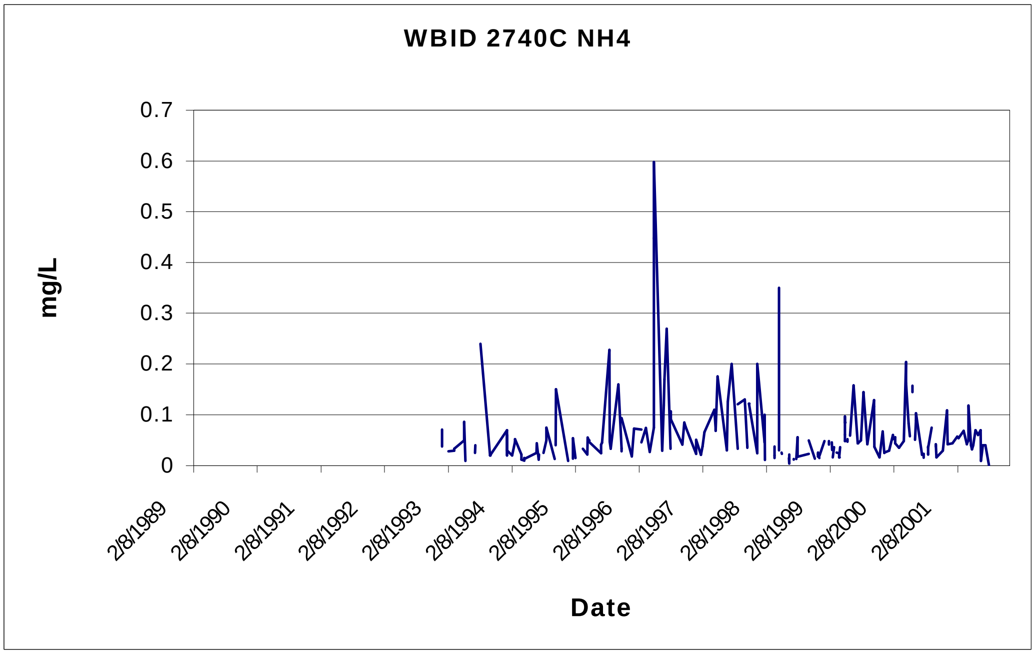


FIGURE 3C: WATER QUALITY TIME SERIES FOR AMMONIA & NITRATE-NITRITE VALID FOR WBID 2740C



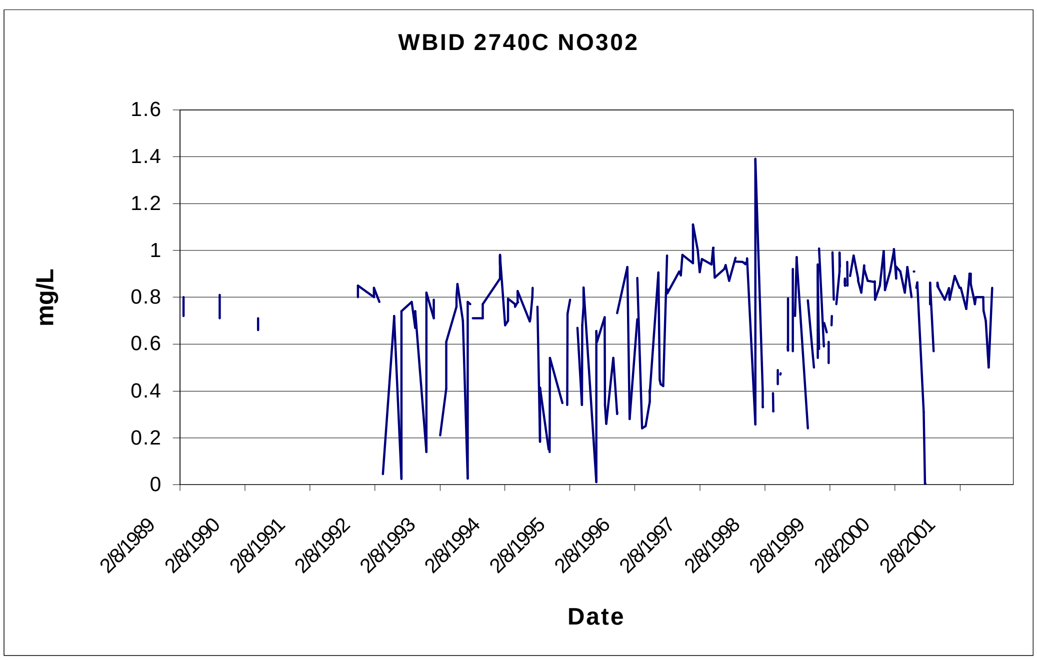


FIGURE 3D: WATER QUALITY TIME SERIES FOR TOTAL NITROGEN VALID FOR WBID 2740C

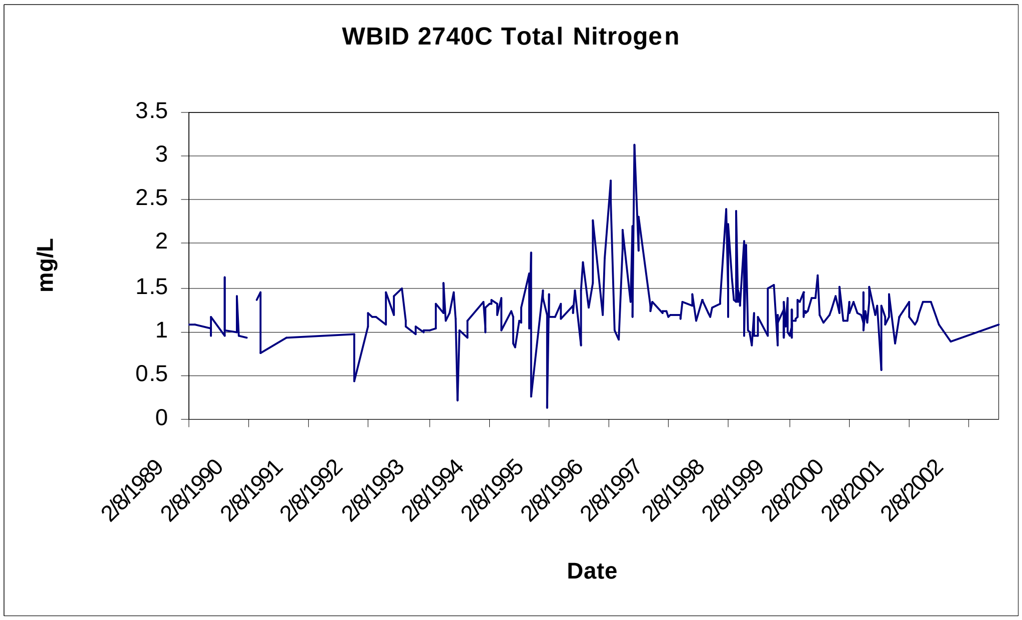
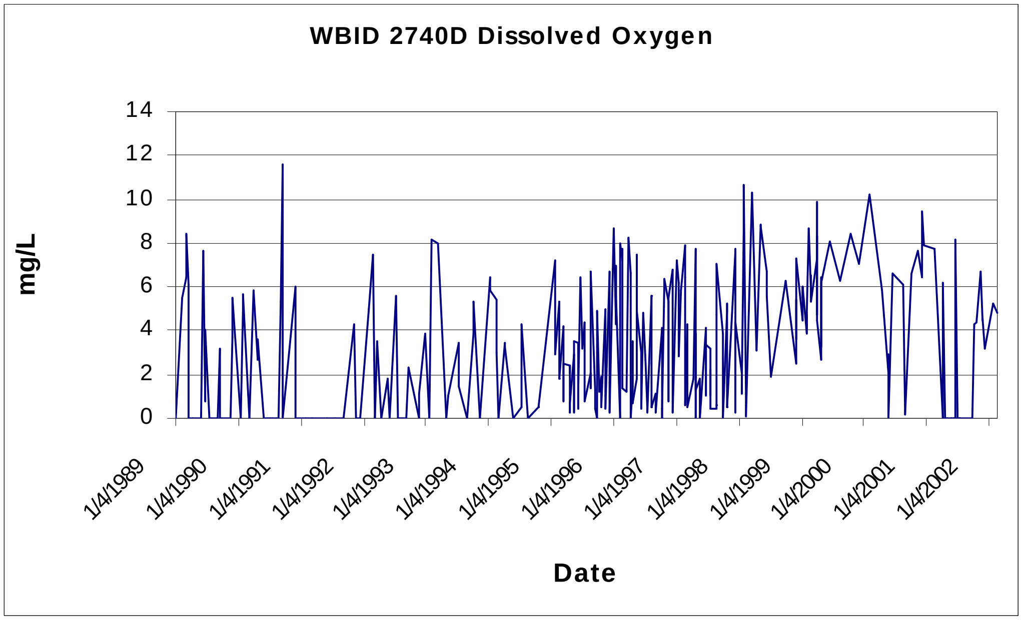


FIGURE 4A: WATER QUALITY TIME SERIES FOR DISSOLVED OXYGEN & BIOCHEMICAL OXYGEN DEMAND VALID FOR WBID 2740D



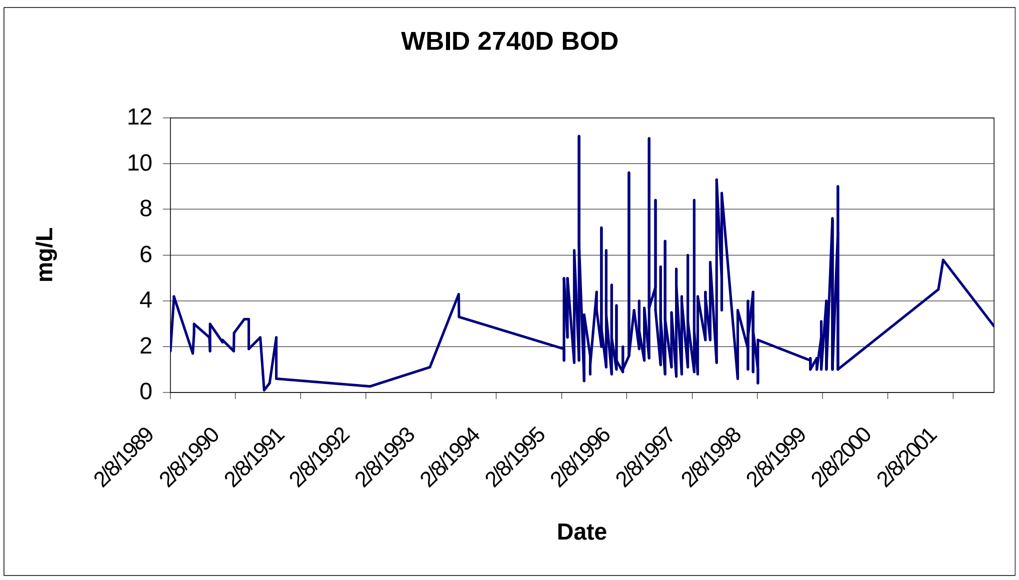
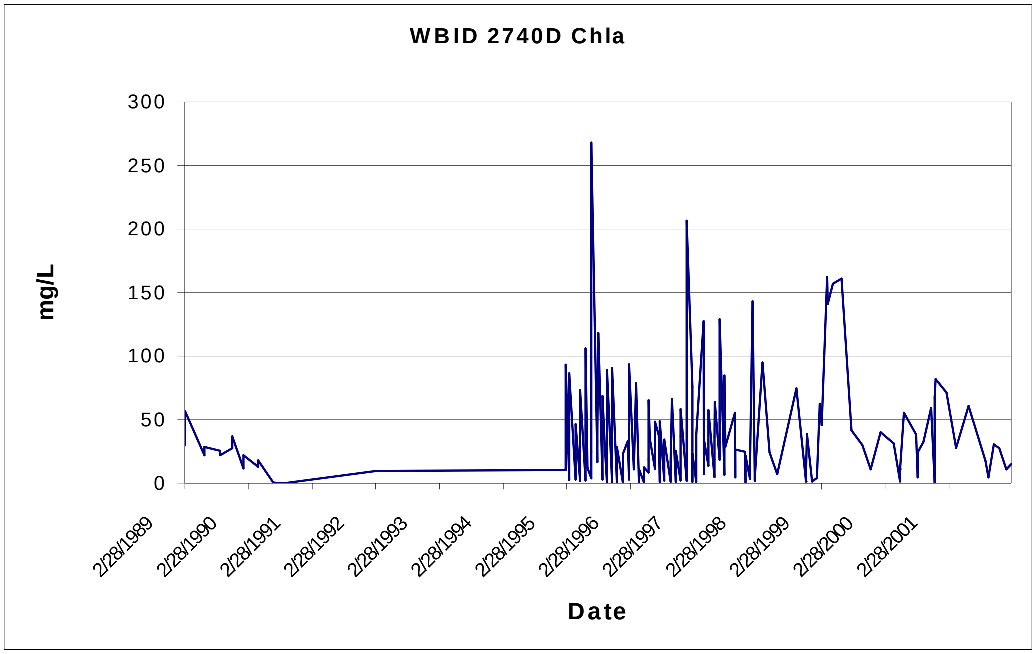


FIGURE 4B: WATER QUALITY TIME SERIES FOR CHLOROPHYLL a & TOTAL PHOSPHORUS VALID FOR WBID 2740D



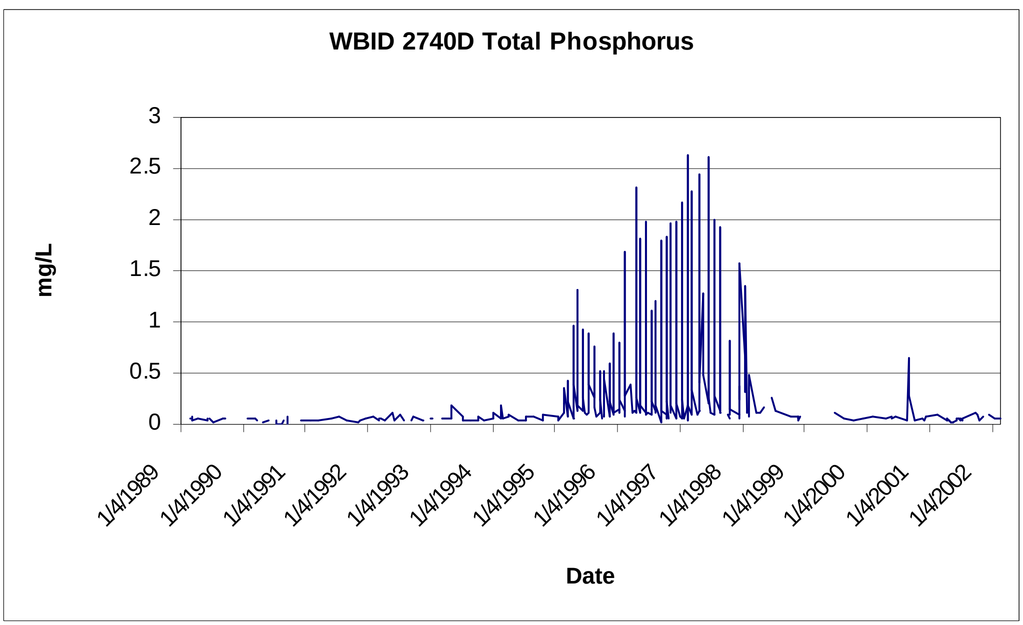
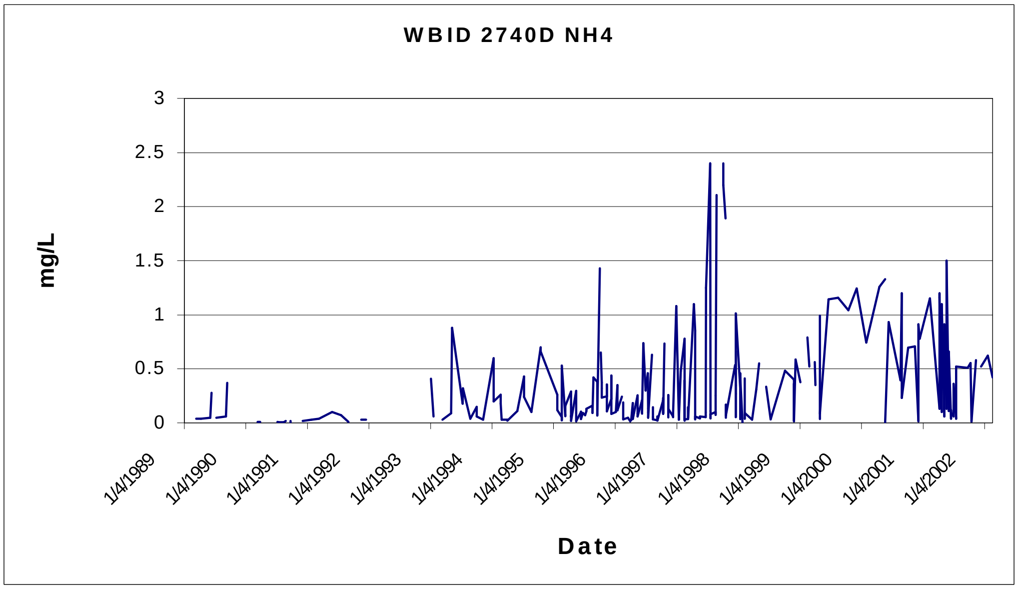


FIGURE 4C: WATER QUALITY TIME SERIES FOR AMMONIA & NITRATE-NITRITE VALID FOR WBID 2740D



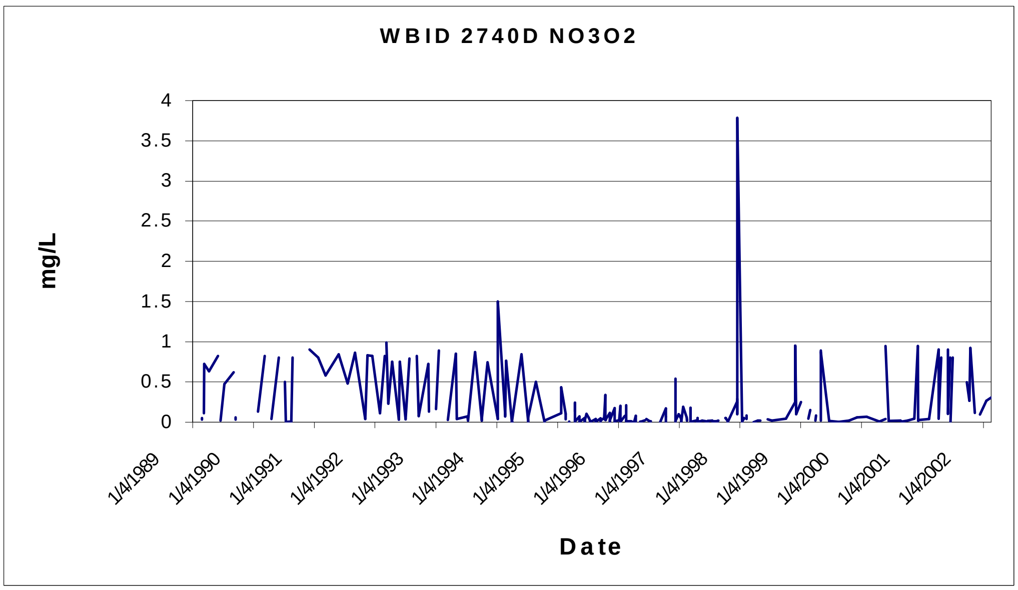


FIGURE 4D: WATER QUALITY TIME SERIES FOR TOTAL NITROGEN VALID FOR WBID 2740D

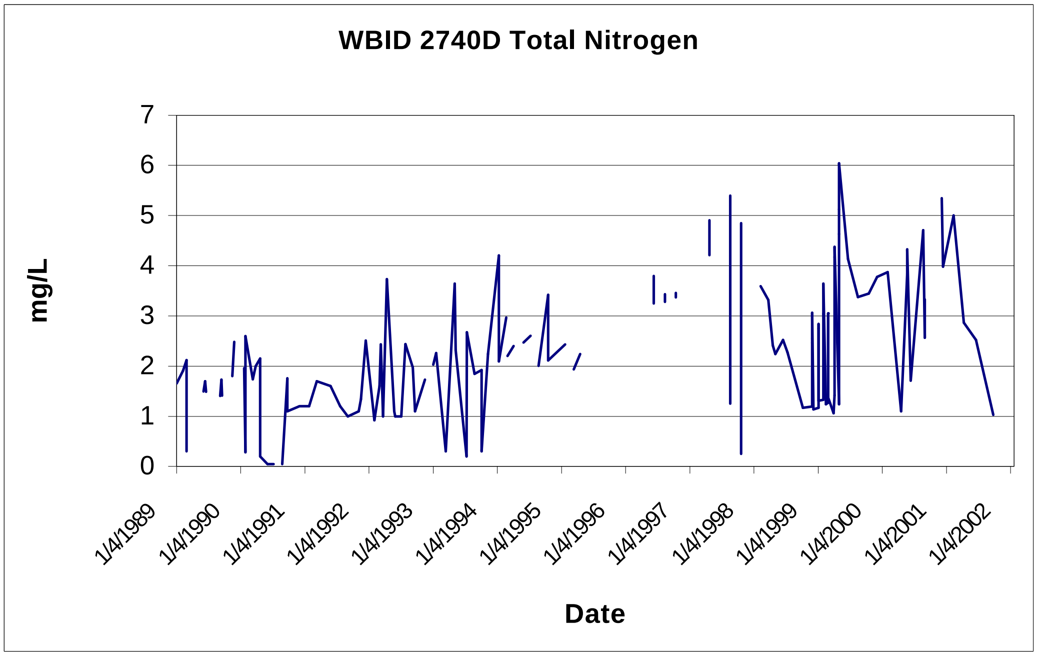
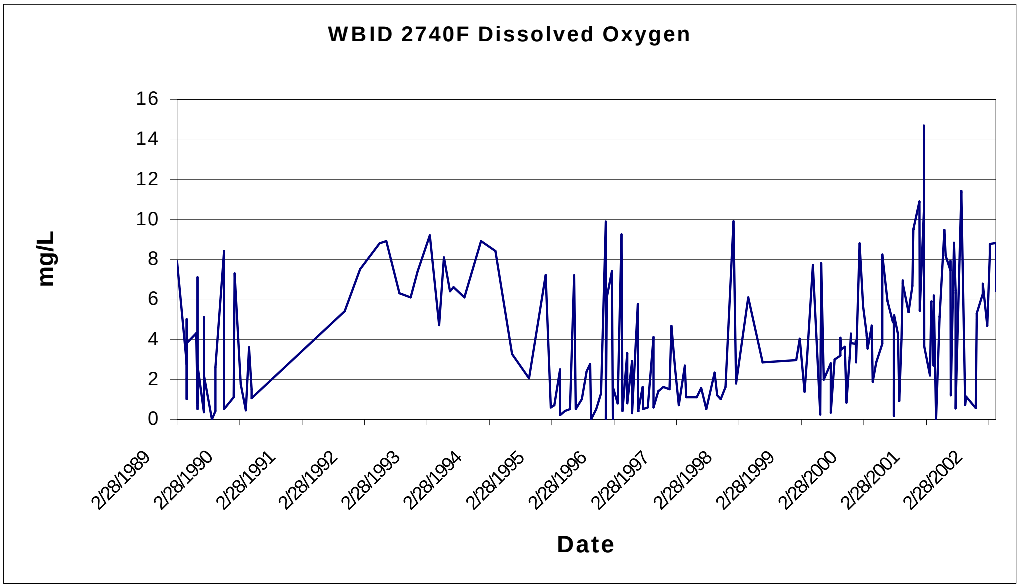


FIGURE 5A: WATER QUALITY TIME SERIES FOR DISSOLVED OXYGEN & BIOCHEMICAL OXYGEN DEMAND VALID FOR WBID 2740F



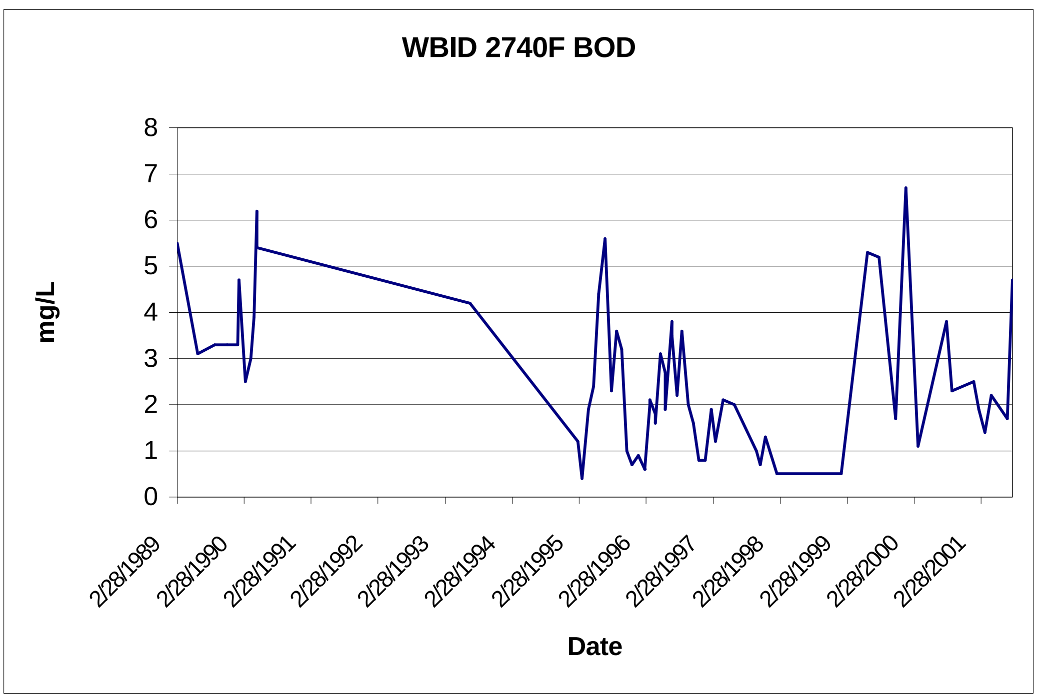
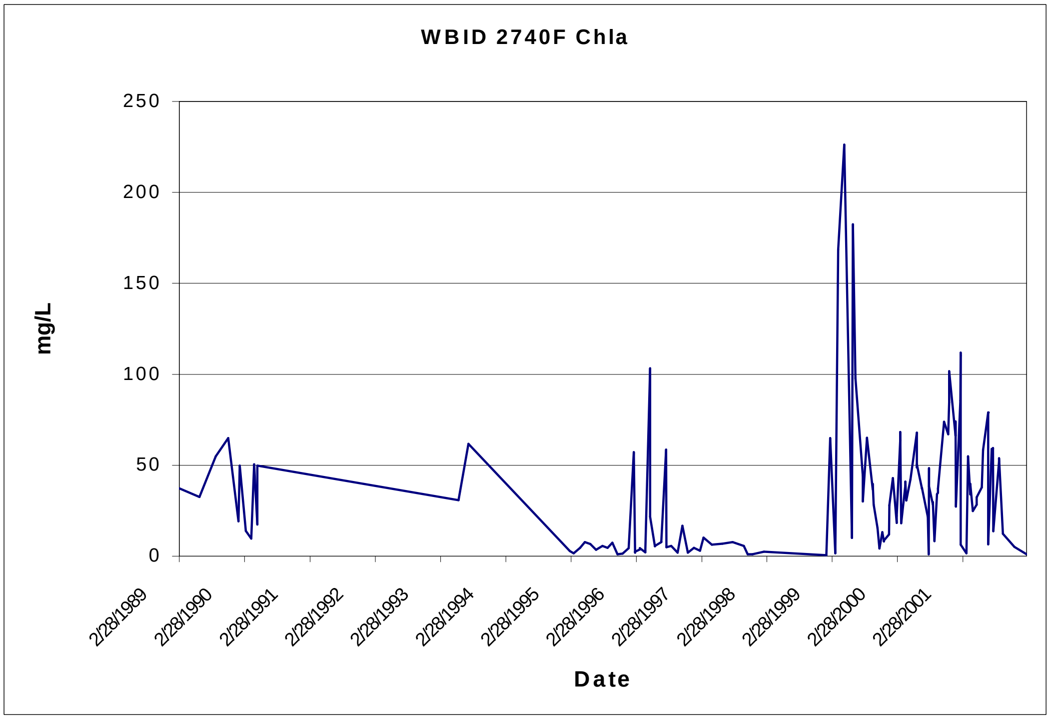


FIGURE 5B: WATER QUALITY TIME SERIES FOR CHLOROPHYLL a & TOTAL PHOSPHORUS VALID FOR WBID 2740F



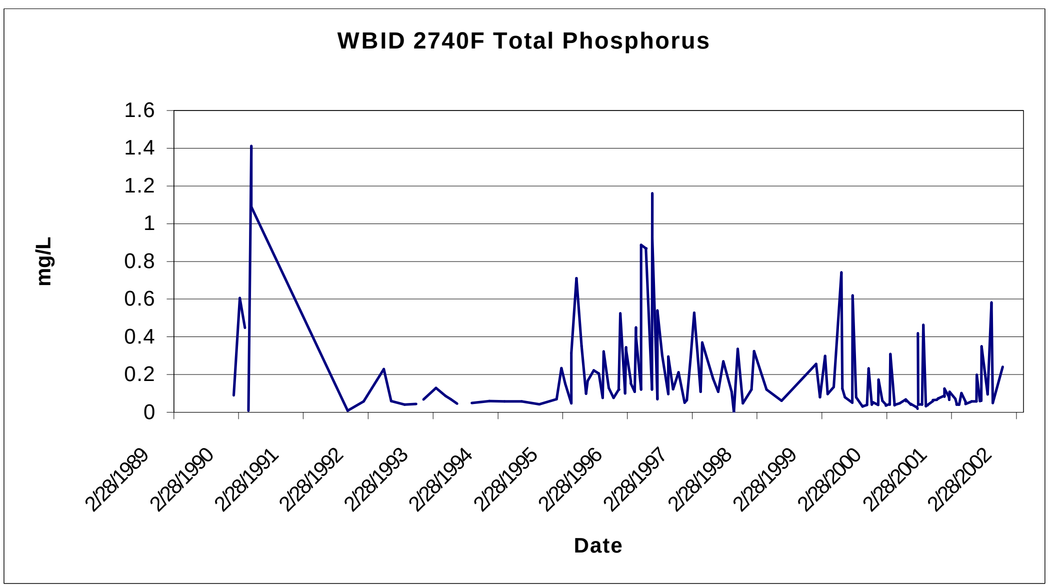
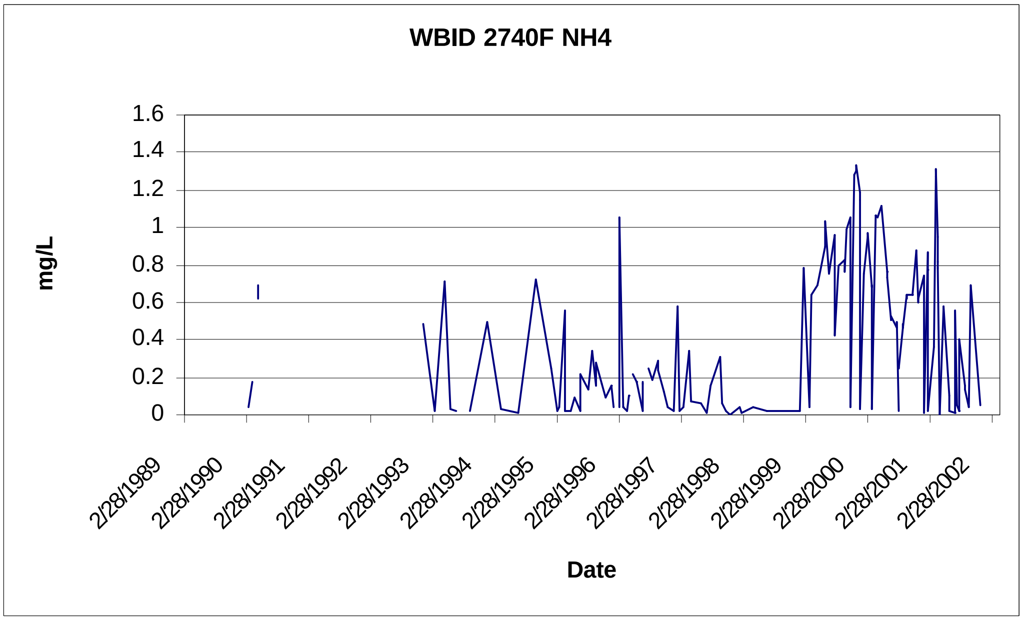


FIGURE 5C: WATER QUALITY TIME SERIES FOR AMMONIA & NITRATE-NITRITE VALID FOR WBID 2740F



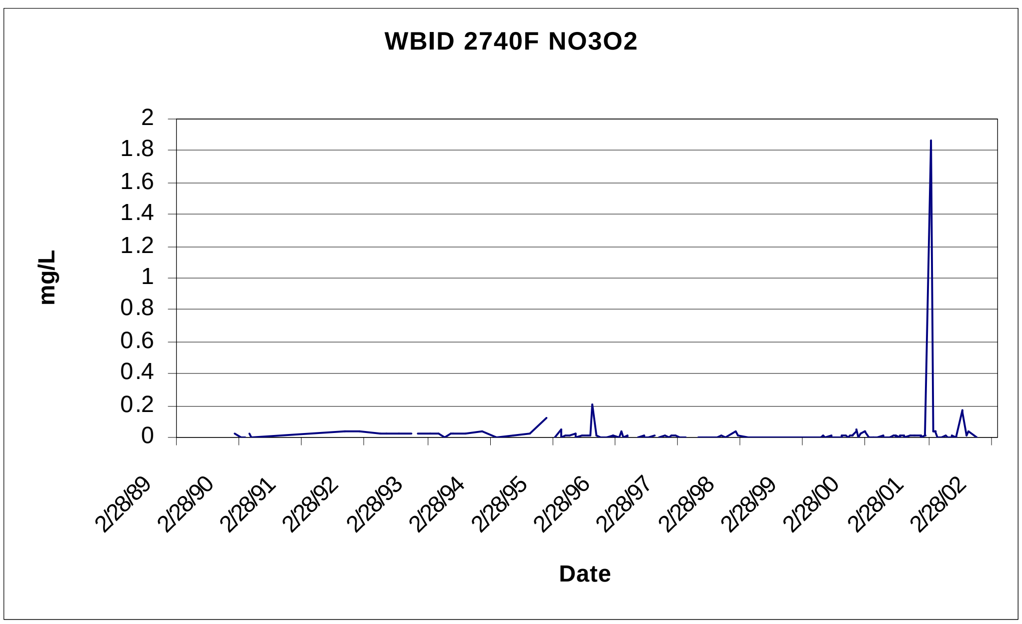


FIGURE 5D: WATER QUALITY TIME SERIES FOR TOTAL NITROGEN VALID FOR WBID 2740F

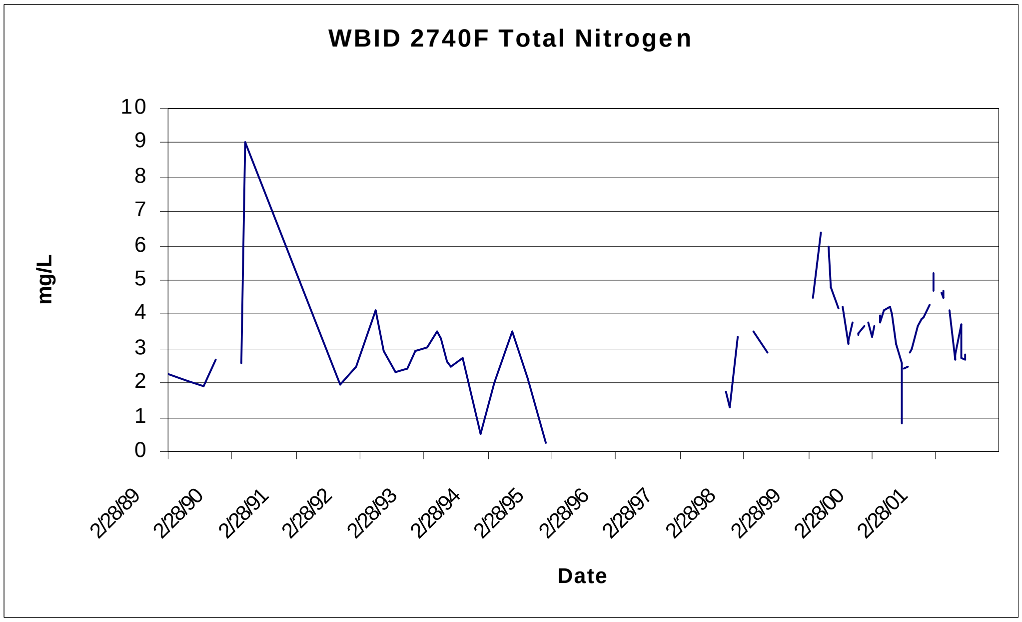


FIGURE 6: LEVEL 1 LAND USE FOR IMPAIRED WBIDs 2740 C, D, & F ALONG THE OCKLAWAHA RIVER

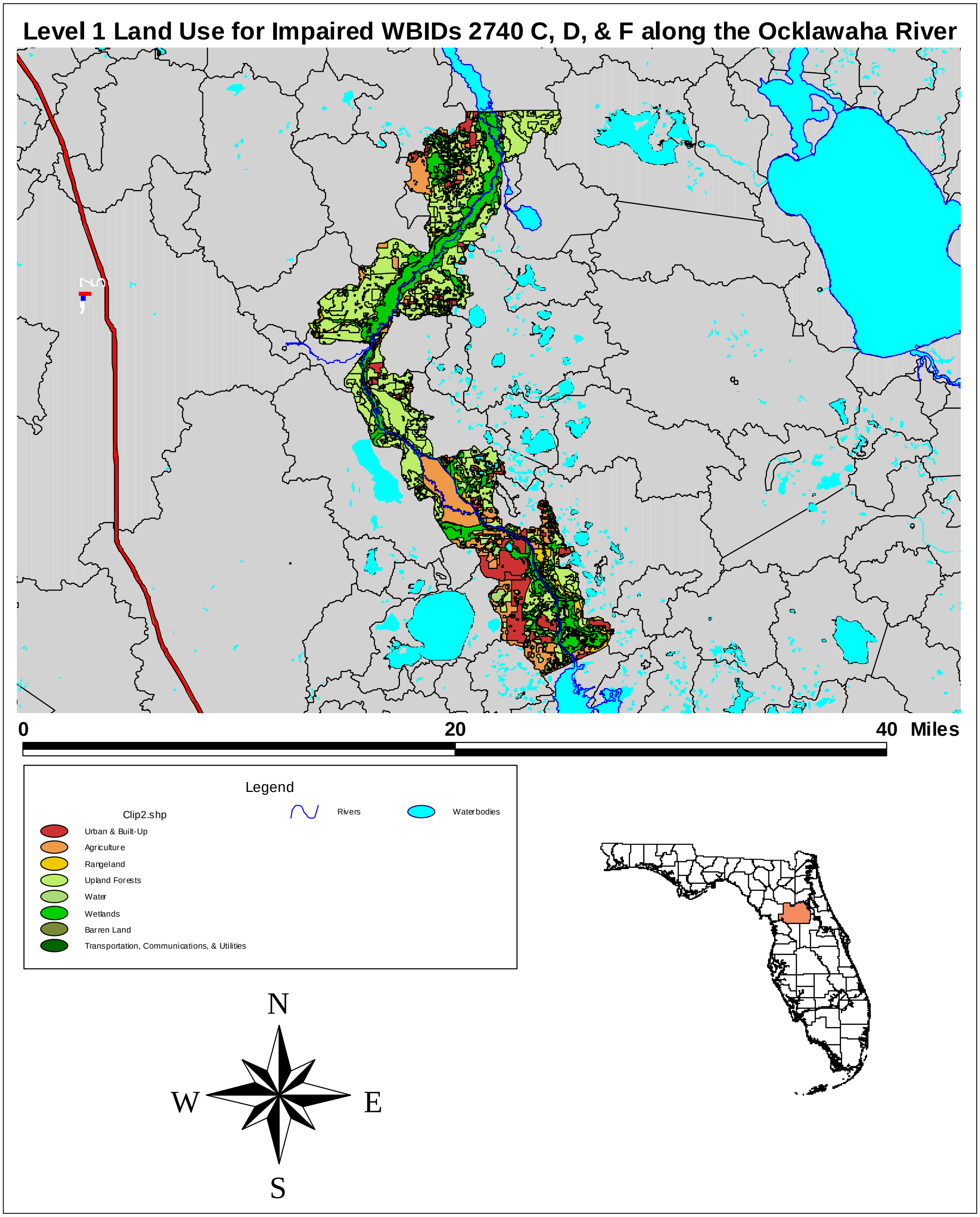


FIGURE 7: POPULATION DENSITY OF MARION COUNTY, FL IN PERSONS PER SQUARE MILE FROM THE U.S. CENSUS BUREAU (2000)

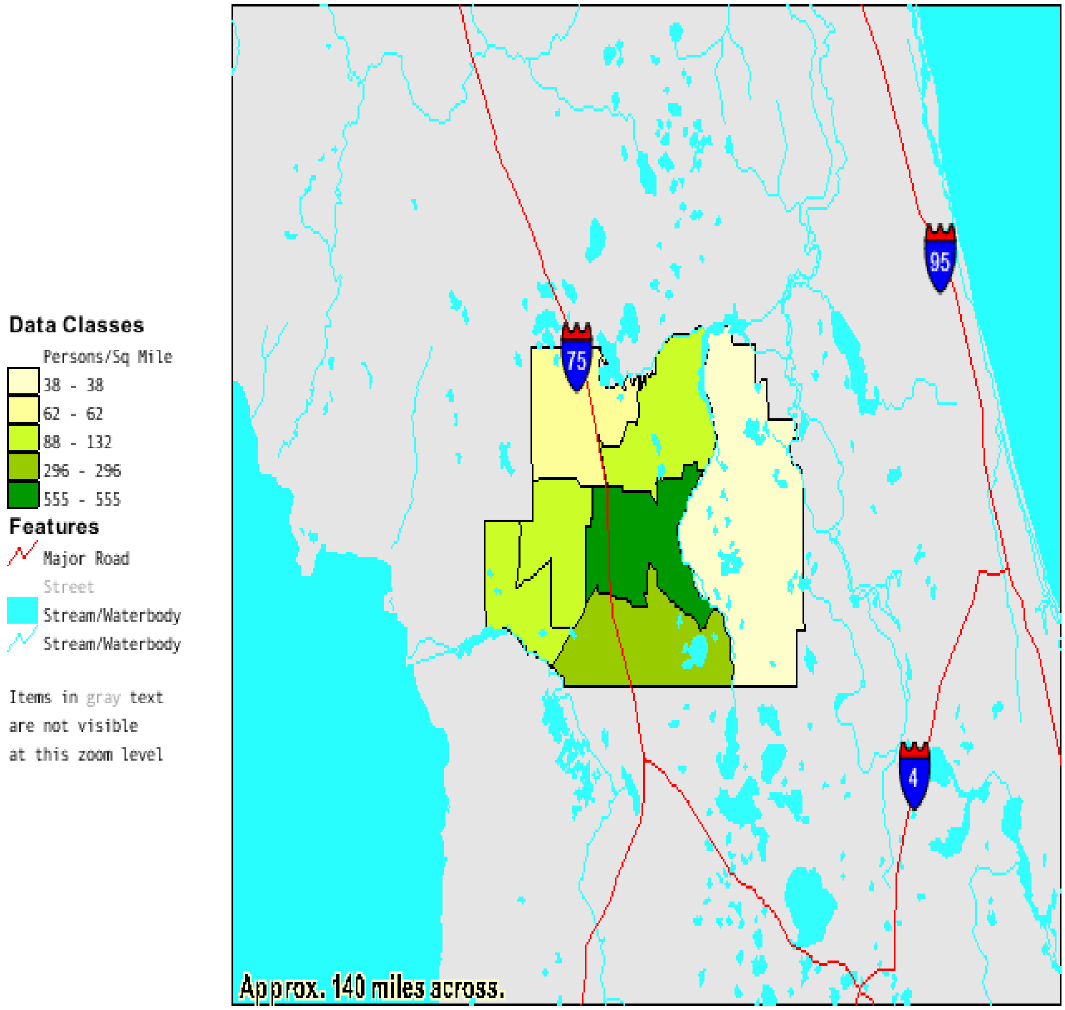


FIGURE 8: MODEL SPATIAL DOMAIN AND CALIBRATION POINTS FOR THE OCKLAWAHA RIVER

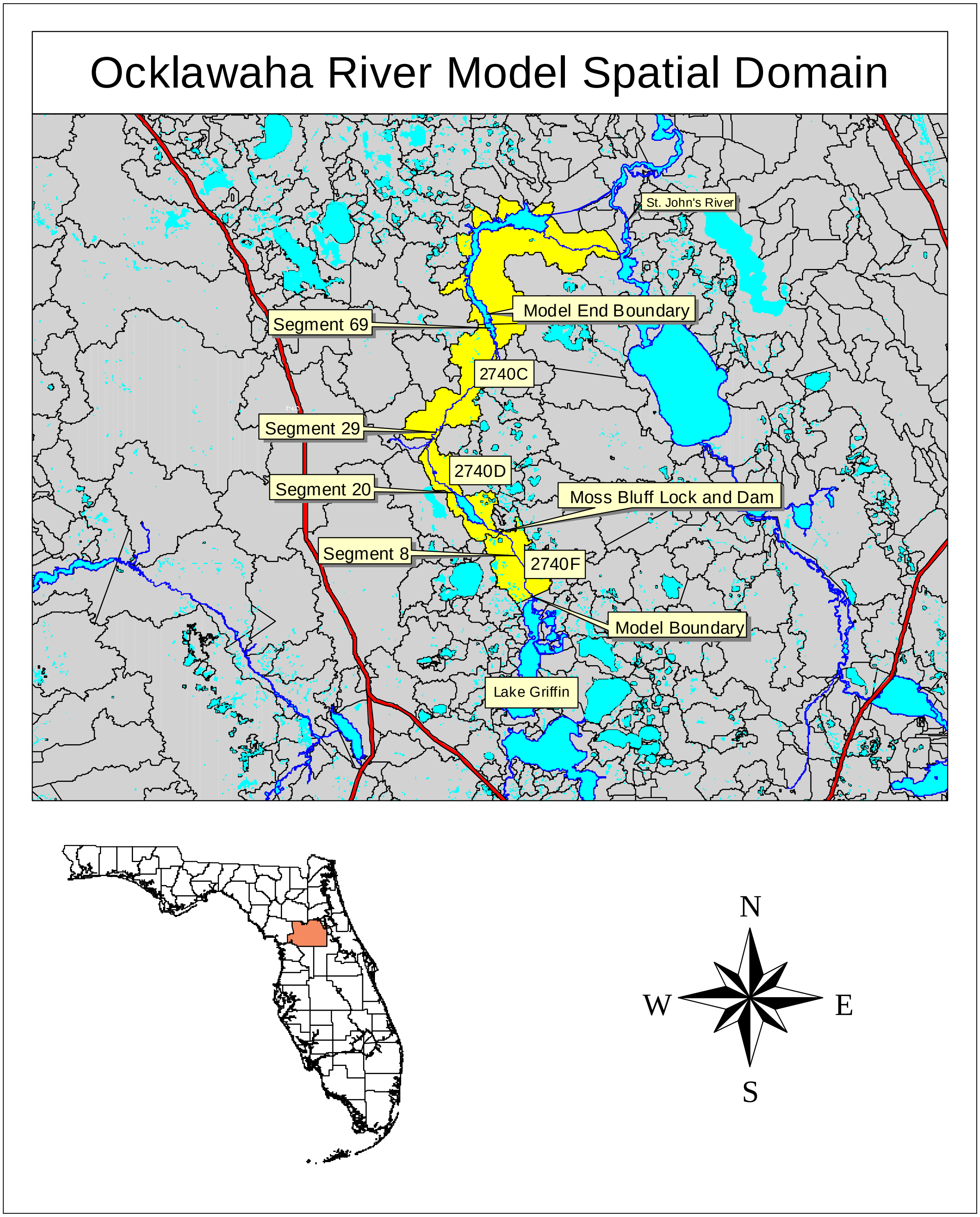


TABLE 1: OCKLAWAHA RIVER CHLOROPHYLL a & DISSOLVED OXYGEN ASSESSMENTS UNDER THE IWR

Year	WBID	Annual Chlorophyll a (μg/L)
1989	2740C	2.0
1994	2740C	6.4
1995	2740C	1.8
1996	2740C	9.4
1997	2740C	3.7
1998	2740C	6.8
1999	2740C	3.3
2000	2740C	7.4
2001	2740C	1.6
1989	2740D	31.0
1995	2740D	41.8
1996	2740D	26.0
1997	2740D	40.6
1999	2740D	45.7
2000	2740D	34.7
2001	2740D	40.7
1989	2740F	47.4
1995	2740F	4.0
1996	2740F	19.5
1997	2740F	6.5
1999	2740F	64.1
2000	2740F	41.7
2001	2740F	36.0
Period	**WBID**	**Dissolved Oxygen (mg/L)**
Planning*	2740C	59/165-Potentially Impaired
Verified**	2740C	59/223-Verified
Planning*	2740D	150/217-Potentially Impaired
Verified**	2740D	133/204- Verified
Planning*	2740F	73/102-Potentially Impaired
Verified**	2740F	78/118- Verified

***Planning period runs from January 1989 to December 1998**
****Verified period runs from January 1995 to June 2002**

TABLE 2: AVERAGE CONCENTRATIONS AND INTRA-SEASONAL VARIABILITIES OF IMPAIRED PARAMETERS FOR WBIDs 2740 C, D, & F, LAKE GRIFFIN, & SILVER RIVER

Season	Identifier	Average Dissolved Oxygen (mg/L)	Intra-seasonal Variability (mg/L)	Average Chlorophyll-a (μg/L)	Intra-seasonal Variability (μg/L)
Winter	2740C	4.54	1.135	4.1	8.9
Spring	2740C	4.17	1.738	5.7	15.6
Summer	2740C	3.66	1.571	7.3	17.9
Fall	2740C	3.38	1.183	1.3	1.2
Winter	2740D	4.94	2.662	31.6	42.2
Spring	2740D	3.85	2.516	40.2	45.0
Summer	2740D	2.89	2.331	37.4	49.1
Fall	2740D	4.21	2.519	25.1	25.6
Winter	2740F	5.55	3.586	29.8	31.9
Spring	2740F	3.91	2.931	43.5	50.9
Summer	2740F	3.71	3.056	36.2	26.3
Fall	2740F	3.62	2.580	27.9	29.7
Winter	Lake Griffin	10.14	1.545	125.1	79.7
Spring	Lake Griffin	8.06	1.802	128.4	128.4
Summer	Lake Griffin	7.11	2.233	134.8	82.3
Fall	Lake Griffin	9.21	1.461	141.8	68.8
Winter	Silver River	5.86	0.855	1.0	0.9
Spring	Silver River	6.07	1.689	1.4	0.2
Summer	Silver River	4.96	1.099	2.0	0.7
Fall	Silver River	4.82	1.458	1.2	0.2

****RED INDICATES VIOLATION OF STATE DISSOLVED OXYGEN NUMERIC CRITERION**

****BLUE INDICATES VIOLATION OF FRESHWATER STREAM NUTRIENT CRITERIA EXPRESSED THROUGH CHLOROPHYLL-A CONCENTRATIONS**

TABLE 5: MODEL LOAD REDUCTION STATISTICS FOR UPSTREAM SEGMENTS 8 & 20

SEGMENT 8	Parameter	Min	Max	Median	Mean	Stdev
Observed	Chl-a (ug/L)	0.59	48.34	5.34	8.03	9.19
No Load Reductions	Chl-a (ug/L)	1.34	57.61	16.63	16.93	9.08
With Load Reductions	Chl-a (ug/L)	0.34	20.26	4.57	4.84	2.89
Observed	DO (mg/L)	0.20	6.10	1.00	1.38	1.27
No Load Reductions	DO (mg/L)	1.60	10.92	4.06	4.58	1.99
With Load Reductions	DO (mg/L)	1.57	10.90	3.70	4.28	2.07
Observed	BOD5 (mg/L)	0.40	6.70	1.95	2.24	1.52
No Load Reductions	BOD5 (mg/L)	1.97	10.16	5.70	5.65	1.74
With Load Reductions	BOD5 (mg/L)	1.72	7.12	4.49	4.50	1.49
Observed	TP (mg/L)	0.03	1.16	0.30	0.35	0.25
No Load Reductions	TP (mg/L)	0.06	2.00	0.14	0.15	0.05
With Load Reductions	TP (mg/L)	0.05	0.26	0.10	0.11	0.03
SEGMENT 20	**Parameter**	**Min**	**Max**	**Median**	**Mean**	**Stdev**
Observed	Chl-a (ug/L)	0.27	268.19	10.69	28.07	47.32
No Load Reductions	Chl-a (ug/L)	0.73	52.45	12.03	13.92	8.97
With Load Reductions	Chl-a (ug/L)	0.18	35.50	3.99	5.59	5.39
Observed	DO (mg/L)	0.30	7.70	1.85	2.67	2.22
No Load Reductions	DO (mg/L)	2.35	10.50	3.43	4.06	1.85
With Load Reductions	DO (mg/L)	2.20	10.45	3.24	3.91	1.86
Observed	BOD5 (mg/L)	0.40	11.20	2.00	3.08	2.72
No Load Reductions	BOD5 (mg/L)	1.18	9.73	4.76	4.83	1.75
With Load Reductions	BOD5 (mg/L)	1.02	6.70	3.69	3.81	1.41
Observed	TP (mg/L)	0.02	2.63	0.32	0.75	0.82
No Load Reductions	TP (mg/L)	0.06	0.29	0.14	0.14	0.04
With Load Reductions	TP (mg/L)	0.05	0.26	0.10	0.11	0.03

TABLE 6: MODEL LOAD REDUCTION STATISTICS FOR DOWNSTREAM SEGMENTS 29 & 69

SEGMENT 29	Parameter	Min	Max	Median	Mean	Stdev
Observed	Chl-a (ug/L)	0.01	81.90	2.67	5.80	13.14
No Load Reductions	ChL-a (ug/L)	0.06	16.99	0.86	2.13	3.21
With Load Reductions	ChL-a (ug/L)	0.01	4.26	0.32	0.67	0.83
Observed	DO (mg/L)	3.10	6.19	4.90	4.85	0.96
No Load Reductions	DO (mg/L)	3.36	8.44	5.76	5.89	1.20
With Load Reductions	DO (mg/L)	3.36	8.41	5.75	5.87	1.19
Observed	BOD5 (mg/L)	1.00	1.30	1.00	1.05	1.05
No Load Reductions	BOD5 (mg/L)	0.65	4.39	0.89	1.23	0.80
With Load Reductions	BOD5 (mg/L)	0.64	4.31	0.84	1.09	0.64
Observed	TP (mg/L)	0.01	2.02	0.05	0.07	0.19
No Load Reductions	TP (mg/L)	0.04	0.12	0.06	0.06	0.01
With Load Reductions	TP (mg/L)	0.03	0.10	0.05	0.05	0.01
SEGMENT 69	**Parameter**	**Min**	**Max**	**Median**	**Mean**	**Stdev**
Observed	Chl-a (ug/L)	0.01	14.41	1.00	1.82	2.33
No Load Reductions	Chl-a (ug/L)	0.06	16.42	0.96	2.24	3.20
With Load Reductions	Chl-a (ug/L)	0.01	4.15	0.35	0.73	0.86
Observed	DO (mg/L)	3.90	10.66	6.40	6.39	1.20
No Load Reductions	DO (mg/L)	4.18	8.29	5.96	6.09	0.94
With Load Reductions	DO (mg/L)	4.16	8.23	5.94	6.06	0.93
Observed	BOD5 (mg/L)	1.00	1.00	1.00	1.00	1.00
No Load Reductions	BOD5 (mg/L)	0.61	4.28	0.85	1.18	0.80
With Load Reductions	BOD5 (mg/L)	0.64	4.31	0.84	1.09	0.64
Observed	TP (mg/L)	0.01	0.09	0.05	0.05	0.01
No Load Reductions	TP (mg/L)	0.04	0.46	0.06	0.06	0.02
With Load Reductions	TP (mg/L)	0.03	0.46	0.05	0.05	0.01